# SYLLABUS OF THE SUBJECTS

IN WHICH

# EXAMINATIONS ARE HELD

BY

# THE DEPARTMENT OF SCIENCE AND ART.

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# SYLLABUS OF THE SUBJECTS IN WHICH EXAMINATIONS ARE HELD BY THE DEPARTMENT OF SCIENCE AND ART.

THE following Syllabus has been prepared in order to afford candidates some guide to their reading; but it must be understood that the questions in the examination need not necessarily be on the specific points enumerated.

The examination is by paper, but oral examination may be resorted to. The examination in each subject is distinct. Mention is made of text-books solely to afford a candidate some assistance in selection and a general idea of the scope of the examination, *and not at all to confine his reading to those works or to assert that they are the best on the subjects they treat of.*

A Course of Lectures as detailed below, on "Preparation for obtaining "Science Certificates and the Method of teaching a Science Class," has been delivered by direction of the Lords of the Committee of Council on Education. The lectures may be purchased, price 2*d.* each, at the book stall, South Kensington Museum, or on application by letter, enclosing postage stamps, to the Secretary, Department of Science and Art, South Kensington, London, W.

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|---|---|
| Geometrical Drawing, &c. | Prof. T. Bradley. |
| Mechanical Physics | Rev. B. M. Cowie, M.A. |
| Chemistry | Prof. Hofmann, F.R.S. |
| Geology | Prof. Ramsay, F.R.S. |
| Mineralogy, &c. | Prof. W. W. Smyth, M.A., F.R.S. |
| Zoology | Prof. Huxley, F.R.S. |
| Botany | Edwin Lankester, M.D., F.R.S. |
| Navigation and Nautical Astronomy. | J. Riddle, F.R.A.S. |
| Physical Geography | Dr. G. Kinkel, F.R.G.S. |

A Second Course has been delivered, of which the following have been published:—

| | | |
|---|---|---|
| Lecture I. | Vegetable Physiology and Economic Botany. | Edwin Lankester, M.D., F.R.S. 3rd February. |
| Lecture II. | Mechanical Physics | Rev. B. M. Cowie, B.D. 10th February. |
| Lecture IV. | Mining | W. W. Smyth, M.A., F.R.S. 24th February. |

# SYLLABUS.

A teacher will not receive any payments for Subjects II. or III. until he is qualified in I.

## Subject I.—Practical Plane, and Solid Geometry.

Practical Geometry, plane and solid; required by architects, engineers, mechanists, shipbuilders, and others employed in arts of construction.

The candidate is assumed to have acquired readiness in the use of the usual drawing instruments and materials, to be skilful in drawing lines and circles in Indian ink, plain or dotted, of different degrees of fineness; drawing parallel equi-distant lines, at least six inches long, and from five to twenty or thirty in an inch; drawing from ten to thirty lines, passing through one point and forming equal angles; dividing by trial lines and arcs into any number of equal parts. He should also be able to mend his drawing pens and other instruments, and to verify his rulers, &c. Two or three questions in the first or easy paper are intended to test his skill in these respects.

### *Constructions in Plane Geometry.*

1. To draw lines through given points, in every position, either parallel, perpendicular to, or to form any proposed oblique angle, with given lines.

   The use and construction of the *protractor*, and of the "scale of chords" for these purposes, should be understood, and the deduction of certain angles from the direct division of the circle.

2. To draw circles or arcs, through given points, to touch given lines or circles, and, conversely, lines to touch circles.

   Required in drawing framework for machinery, architectural designs, ornamentation, &c.

3. The principles of drawing symmetrical forms by means of co-ordinates to the axis of symmetry.

   This is the basis of all drawing, of objects of construction, which are always symmetrical, not only in architecture, civil and naval, but in machinery and engineering works of all kinds.

4. Constructions of figures *similar* to given rectilinear or mixtilinear figures.

   Here the construction and use of "scales" plain and comparative, should be thoroughly understood and explained, and the principles of the *diagonal* division of scales. Also the mode of reducing or enlarging drawings by means of similar rectangles, termed *squaring* a drawing. The use of the sector and of proportional compasses in facilitating copying should be known.

5. To construct rectilinear figures similar to given ones, but with a proposed area.

6. To determine by construction numerical quantities such as $\sqrt{m}$; $\sqrt{\frac{1}{m}}$; $\sqrt{a^2 \pm b^2}$, &c.

7. To construct a triangle, any three parts being given.

§ 1. Used in levelling, surveying, and the determination of heights and distances. Great accuracy, neatness, and distinctness of construction, will be insisted on: Geometrical drawing is valueless unless it possesses these requisites.

§ 2. A few illustrations of constructions on the ground, by means of a "chain," pins and cords, necessary in surveying, and "setting out" buildings and earthworks, may be added to the course, as well as the solution of a few elementary problems by means of the compasses alone.

8. The delineation of a few of the curve lines required in the arts, such as the ellipse, cycloidal curves, the involute and sinusoid, with the graphical method of determining their tangents and normals.

Required in designing elliptic arches, oblique bridges, teeth of wheels, cam-work, screws, &c.

9. Practice in tinting and shading with Indian ink, so as to express curved surfaces and shadows.

Both papers contain questions from sections, 1, 2, 4, 5, but those of the second or more difficult paper are chiefly from sections 4, 5, 7, and 8, and only rarely from 3, 6, 7, and 9.

For the preceding part of the course, a fair knowledge of the first four books of Euclid is necessary, some acquaintance with elementary trigonometry is also desirable.

### *Constructions in Solid Geometry.*

(*Descriptive Geometry.*)

A general knowledge of the principles of *projection* on two (co-ordinate) planes, as necessary to define or represent any geometrical solid, is necessary to gain any certificate in this subject. These projections are termed *plans, elevations, profiles,* or *sections.*

The questions in the first or easy paper demand only this elementary knowledge, the candidate being required to represent by their projections simple solids, such as prisms and pyramids, or others formed by their combinations.

But to obtain a second or first class the candidate must be acquainted with the methods of solving problems on the combinations of points, lines, and especially planes, independent of any solid form or *volume* of which they are the elements.

He should also know something of the geometry of *curved surfaces,* as the sphere, cylinder, and cone, and of the mode of representing all surfaces graphically by the projections of their generators. For the following subjects he must know how to determine planes to touch or tangential to such surfaces; but candidates are not expected to be more than generally acquainted with these subjects. Occasionally, however, easy questions in the following are inserted in the second paper.

Applications to the intersections of surfaces, and of the development of such as admit of it.

This may be considered the most important part of descriptive geometry to the artizan, as it is required in all arts of construction. The mason, carpenter, and shipwright, workers in tin-plate, boiler makers, &c., must all possess some knowledge of it.

The solution by construction of the spherical triangle from any three given parts, is mentioned.

As important to masters, mates, and others engaged in any kind of astronomical calculations.

*Isometric Projection*

Is usefully employed in the representation of works, chiefly of a rectangular form, such as timber framing, canal-locks, and many parts of machinery; its use is increasing: it is readily understood, and can be practised by anyone who has gone through the previous articles of this section.

*Perspective or Radial Projection*

May be taken up, but will not be insisted on as it is rarely used except by architects to represent buildings (not yet executed), as they would appear to the eye at any spot from which they could be viewed, and the power of applying it for this purpose is possessed by many who know little of the really easier subject of descriptive geometry; but as its application by the architect must be subordinated to artistic taste, this consideration excludes it, in some measure, from a purely geometrical course.

No one, however, can be considered a scientific draughtsman unless he can apply perspective projection to the projection of shadows, the projections of the sphere, the constructions of maps and dials, and some other uses.

For the second division of this course, in addition to what was before indicated, a competent knowledge of the theorems relating to the line and plane (Euclid, Book XI.) is essential.

The following are some of the best works on the subject of Practical Geometry, but the list is not given as a complete one:—

For Theoretical Geometry.—1. *Geometry, Plane, Solid, and Spherical, &c.* (Library of Useful Knowledge), published originally by Baldwin and Cradock, undoubtedly the best work on the subject.—2. *Geometry, &c.*, by Mr. Bell, in Chambers's Educational Course, both comprehensive and excellent.—3. There are excellent elementary works based on Euclid in Gleig's School Series, and in that published by Messrs. Galbraith and Haughton in Ireland, also in Weale's Series, &c. &c.

For Practical Geometry.—Bradley's *Geometrical Drawing*, published for the Committee of Council on Education by Messrs Chapman and Hall. — Bradley's *Practical Geometry, Perspective and Projection* (Library of Useful Knowledge). — Hall's *Elements of Descriptive Geometry for Students in Engineering*.—Heather's *Descriptive Geometry for Students in Engineering* in Weale's Series.—Also works by Winter, Burchett, and Binns.

French works on this subject are numerous and excellent, by Lacroix, Lefebre de Fourcy, Leroy, Le Vallée, Adhemar, Bardin, &c. &c.

**Subject II.—Machine Construction and Drawing.**

The application of the foregoing Subject I. to the drawing of machinery, in which great accuracy and neatness of drawing will be insisted on.

The candidate will be required to take measurements with calipers, &c., and to make drawings, elevations, and sections of a simple machine, or of parts of one, set before him. Also to draw a portion of a machine from written dimensions and description. He will be required to have sufficient knowledge of the principles of machinery, gearing, &c., to be able to make working drawings of a machine or portions of a machine from a rough sketch, applying the power to the greatest advantage, and obtaining such power or changes of motion as are required. In fine, such knowledge and readiness as would be required of a good draughtsman in an engineer's office.

**Subject III.—Building Construction, *or* Naval Architecture and Drawing.**

(*See previous Subject.*)

The candidate will be required to possess sufficient knowledge of construction—(1) to apply the various materials used in building to their greatest advantage; (2) to be able to make detail and working drawings showing a knowledge of the methods of construction and the framing of ordinary roofs, bridges, &c., whether of wood, iron, or masonry; (3) to frame estimates and take out quantities.

Neatness, accuracy, and facility in drawing will be insisted on, and the general requirements in this Subject will be such as would be possessed by a good draughtsman in an architect or builder's office, with a slight scientific knowledge for the proper application of the materials he is required to work with.

N.B.—Naval Architecture may be taken instead of Building Construction; the same description of attainments will be required.

**Subject IV.—Elementary Mathematics.**

1. *Arithmetic generally.*
2. *Geometry.*—The properties of lines, triangles, rectilinear figures, the circle; properties of similar figures; proportion of figures; inscribed and circumscribed polygons. The questions will have reference to Euclid's elements; but a sound knowledge of Geometry obtained from any source will be accepted.
3. *Algebra.*—Definitions. Addition. Subtraction. Multiplication. Division. Greatest common measure. Least common multiple. Theory of indices (integral). Involution. Evolution. Simple equations, and problems producing them. Fractions. Quadratic equations, and problems producing them. Ratio. Proportion. Variation. Arithmetical, geometrical, and harmonical Progressions, Permutations, and Combinations. Binomial theorem for a positive integral index.
4. *Plane Trigonometry.*—Definitions. Conversion of degrees and their subdivisions into grades, and their subdivisions, and *vice versâ*. Angular and circular measures of degrees and their relation. The goniometric functions of angles and the conversion of one into another. The arithmetical values of the goniometric functions of 90°, 45°, 60°, 30°, 180°, 120°, 150°, &c. The meaning of contrariety of signs in trigonometry. Tracing of the goniometric functions in magnitude and algebraic sign through the four quadrants and when an angle is indefinitely increased.

Formulæ for multiplication and division of angles, viz., sine, cosine, tangent, &c., of $(A \pm B)$, $2A$, $3A$, $\frac{A}{2}$, and $\frac{A}{3}$. Also of $A$ and $B$ in terms of $\frac{A+B}{2}$ and $\frac{A-B}{2}$.

*Logarithms.*—Definition. Multiplication, Division, Involution and Evolution by logs. The use of logarithmic tables. Tables of proportional parts for numbers and angles. Modulus. Construction of logarithmic tables, and of tables of logarithmic sines, cosines, &c.

*Triangles.*—Formulæ for cosine of an angle of a triangle in terms of its sides. The relation between sines of angles and the opposite sides; sine, cosine, tangent, &c., of half an angle of a triangle in terms of sides, and of the sine of an angle. Area of a triangle. Solution of triangles. Diameters of circles inscribed in and circumscribed about a given triangle. Areas of regular polygons inscribed in and circumscribed about a given circle. Area of a circle. Description and use of vernier and theodolite and sextant (generally). Heights and distances of inaccessible objects.

For students to obtain a 5th class, a competent knowledge of the following alone will be required:—

(1.) Geometry. The first book of Euclid.
(2.) Algebra, to simple equations and problems (inclusive).
(3.) Plane trigonometry. The more elementary portions, including use of logarithms.

To obtain a 4th class:—

(1.) Geometry. The first three books of Euclid.
(2.) Algebra, to quadratic equations.
(3.) Plane trigonometry as far as solution of triangles, inclusive.

And for third, second, and first class Queen's prizes the remaining portion of the above subjects.

### Subject V.—Higher Mathematics.

1. *Algebra.*—Surds. Theory of indices (fractional and negative). Binomial theorem generally. Multinomial theorem. Exponential theorem. Indeterminate equations and problems. Indeterminate coefficients. Reversion of series. Properties of numbers.

2. *Plane Trigonometry.*—De Moivre's theorem and the expansion of sine, cosine, and tangent in terms of the angle.

*Spherical Trigonometry.*—Definitions and fundamental propositions. Polar or supplemental triangle and its properties. Area of a spherical triangle. Spherical excess.

Fundamental formulæ expressing the relations of the sides and angles of a spherical triangle.

Napier's analogies.

Solution of right-angled spherical triangles and of oblique angled triangles.

*Mensuration.*—Trapeziums. Regular plane rectilinear figures. Irregular plane curvilinear figures (Simpson's or Stirling's Rules). Volumes and surfaces of Parallelopipeds, Pyramids, Cylinders, Cones, and Spheres.

*Differential and Integral Calculus.*—Definitions. Differential of elementary functions, including circular and logarithmic functions. Vanishing fractions. Maxima and minima of one independent variable. Tangents and normals of curves. Differential coefficients of Areas, Arcs, Volumes and surfaces of solids of revolution.

Integration of elementary functions. Integration by parts. Rational fractions. Integration between limits. Areas and lengths of simple curves. Volumes and surfaces of solids of revolution.

### Subject VI.—Mechanics as a Science, or Theoretical Mechanics.

Statics. Composition and resolution of forces. Forces acting on a point—on a rigid body. Parallel forces. Centre of gravity. Theory of moments or couples. Principle of virtual velocities. The mechanical powers. Friction. Equilibrium of roofs and arches.

Dynamics. Laws of motion. Uniformly accelerated motion. Motion by gravity Variable forces. Projectiles. Centrifugal force. Motion on inclined planes—on curves. Pendulums. Motion of rigid bodies, free or constrained. Moment of Inertia. Centre of oscillation—of percussion. Motion of flexible bodies, such as a musical string.

Hydrostatics, Hydrodynamics, and Pneumatics. Mechanical properties of liquids. Law of pressure. Centre of pressure. Laws of floating bodies. Capillary attraction. Laws of fluid motion, through open channels, closed pipes, or orifices.

Mechanical properties of elastic fluids. Theory of barometers. Connexion between pressure, temperature, and volume. Specific heat. Weight of atmosphere. Use of barometer in calculating heights.

In this subject the candidate will have to show a mathematical knowledge of the laws of Mechanics, and must be able to prove from first principles the principal theorems.

The books recommended for study are—Whewell's *Elements of Mechanics*, or Snowball's; Moseley's *Engineering Architecture; Natural Philosophy*, by Dr. Golding Bird and Mr. Brooke; Goodwin's *Elementary Course.*

### Subject VII.—Mechanics as an Art, or Applied Mechanics.

General principles of mechanism. *Elementary combinations.* When the connexion is by rolling contact, sliding contact, wrapping connectors or linkwork, with constant or varying velocity ratio, and constant or varying directional relation.

*Machines* of ordinary occurrence must be thoroughly understood and particular parts to be described and drawn: such as cranes; lathes; drills: planing, punching, boring, shaping, and slotting machines. Spinning and weaving machinery. Mode of calculating power of machinery. Dynamometers, indicators, &c.

*Materials.* The general properties of materials. Elasticity. Weight. Specific weight. Mechanical work. Work done by pressure, by impact, by expansion of elastic gases and steam, by animal muscular effort.

Resistance to expansion, to compression, to rupture. Friction of solids. Its importance in construction. Resistance of fluids to bodies moving within them. Adaptation of form and material for maximum resistance. Beams of greatest strength. Construction of roofs, arches, stone and timber bridges, suspension bridges, and tubular girders.

Hydrostatics, Hydrodynamics, and Pneumatics. Pressure on floodgates; locks; water-wheels; turbines; water-pressure engines; breakwaters. Hydrometers. The syphon. Hydraulic ram. Pumps. Diving bell. Condenser. Windmills. Steam-engines, stationary, marine, locomotive. The steam hammer. Water supply to towns. Theory of tides, in the open sea, and in rivers.

In this subject the candidate will be expected to show how the principles are applied in actual practice: he will be expected to show by clear well-drawn sketches, his acquaintance with parts of machines.

The candidate will have tools and models put before him, with some of which he must show he is familiar, and that he can explain their use and construction.

Books recommended:—Willis's *Mechanism;* Baker's *Elements of Mechanism;* the books in Weale's Series which treat on the subjects specified. Twisden's Practical Mechanics; Goodeve's Elements of Mechanism.

### Subject VIII.—Acoustics, Light, and Heat.

#### *Acoustics.*

The candidate ought to know the manner in which sound originates, and is propagated; its velocity in different media, and how its velocity through air is affected by density and temperature.

He ought to know the origin of musical sounds; of pitch; of harmony and discord; to commit to memory the rates of vibration of the several notes of the gamut; to be able to make sonorous vibrations visible by means of glass plates and membranes; to calculate the length of sonorous waves, and to determine practically the number of vibrations due to any particular note. He ought therefore to understand the construction and use of the Syren.

He ought to be able to describe and illustrate the condition of a vibrating string, or column of air at its nodal points and ventral segments and to explain echos and resonance.

#### *Light.*

The candidate ought to know how its velocity was first determined from observations upon Jupiter's satellites.

He ought to be able to devise a simple means of exhibiting both the reflection and refraction of light; to be able to state the laws of both; to explain what is meant by total reflection; and to apply it to the explanation of the Mirage of the Desert, the Phantom Ship, and other similar phenomena.

He ought to be able to explain why the image in a plane mirror must appear as far behind the mirror as the object is in front of it; why a stick appears bent when dipped obliquely into water; and why the bottom of a river or lake, or of a basin which holds water, appears to be nearer to the surface than it really is.

He ought to be able to determine the positions of the foci of spherical mirrors, both concave and convex; to describe the characters of their images, whether erect or inverted; magnified or reduced; and to do the same for convergent and divergent lenses.

He ought to know the construction of the human eye; the conditions of distinct vision, the use of spectacles; and to be able to describe a simple form of the reflecting and refracting telescope and of the microscope.

He ought to know the constitution of light; to be able to describe the spectrum produced by refraction with a prism; to explain the origin of colours, and to give a clear explanation of the rainbow.

#### *Heat.*

The candidate ought to be able to describe the construction and graduation of an ordinary mercurial thermometer; to understand the scales of Fahrenheit, Celsius, and Reaumur.

He ought to have clear ideas of conduction and radiation; to be able to devise some simple means whereby the conductive and radiative powers of different bodies may be determined; to explain fully the formation of dew, and to state the conditions favourable to its production.

He ought to know the effect of heat upon the volumes of bodies; to know what is meant by the coefficient of expansion, and how it may be determined; to give illustrations of the enormous power of heat in

producing expansion; to state exceptional cases; to know the manner in which heat is propagated through liquids and gases, as distinguished from ordinary conduction; and to be able to combine two metals possessing different coefficients of expansion, so as to form a compensating pendulum.

He ought to know the meaning of latent heat and of specific heat, and to illustrate both by reference to ice, water, and steam; he ought to be able to show the influence of the high specific heat of water upon an island climate.

He ought to know the strict physical meaning of ebullition; and the influence of pressure upon the boiling points of liquids; he ought to have a general knowledge of the origin of winds and clouds, and to be able to explain the fact that the rain-fall upon the south-west side of a mountain chain in England and Ireland is much more copious than on the north-east side.

Text Books:—See next subject.

### Subject IX.—Magnetism and Electricity.

#### *Magnetism.*

The candidate ought to know the action of one loadstone upon another which is freely suspended, or set afloat upon a liquid; he must have a perfectly clear notion of magnetic polarity, and of the action of magnetic poles upon each other.

He must know the difference between the action of magnetised and unmagnetised steel upon a magnetic needle; also the difference between soft iron and hard steel, with regard to their acceptance and retention of the magnetic condition; (coercive force).

He must be able clearly to state the condition of a mass of soft iron when under the influence of a magnet, and in virtue of which condition the iron is attracted; (magnetic induction).

He must be able to describe the action of the earth upon a magnetic needle; must know the meaning of declination, inclination or dip, and of secular and diurnal variation; the action of the earth upon a bar of soft iron according as it is held in the direction of the dip or at right angles to this direction; finally, the effect of percussion in rendering the condition assumed by the bar of soft iron a permanent one.

He ought to be able to compare accurately the strength of one magnet with that of another, and to state how the relative intensity of the earth's magnetism at two points of its surface may be ascertained.

#### *Frictional Electricity.*

The candidate ought to know various simple ways of exciting electricity to be clearly informed as to the duplex character of the force; to know the condition of the rubber as well as that of the body rubbed; and to be conversant with various forms of electroscopes and electrometers.

He ought to know the foundation of the terms vitreous and resinous, positive and negative; to be able to illustrate the action of two electrified bodies upon each other; and to tell at once whether a body is positively or negatively charged.

He ought to have a clear knowledge of electric conduction, insulation, and induction; and be able to explain the state of a neutral conductor when acted upon by an electrified body; he ought to be able to prove, experimentally, that though we cannot by breaking a magnet obtain two halves each with a single pole, we can by breaking an electrified body obtain two halves each charged with a single electricity.

He ought to be able to explain the influence of points and flames when attached to an electrified conductor; and to describe the action of lightning conductors.

He ought to be able to describe the electric machine, and the electrophorus; and to explain the action of the condenser and of the Leyden jar.

He ought to be able to state the principal effects of the electric discharge; to state the atmospheric conditions necessary to the production of a thunderstorm; and to give a clear account of the so-called return stroke.

*Voltaic Electricity.*

The candidate ought to be able to state precisely how voltaic electricity may be generated; to describe Volta's pile, and his crown of cups; and also the batteries of Daniell, Grove, and Bunsen.

He must have a clear conception of what is meant by the direction of an electric current; and be able to illustrate in the fullest manner the action of a current upon a freely suspended magnetic needle. Given the direction of the current, he must be able to state how the needle moves; given the movement of the needle, he must be able to infer from it the direction of the current.

He must be able to describe fully the action of a current upon soft iron; and to infer from the direction of the current the nature and position of the magnetic poles, which it excites.

He must be well acquainted with the chemical reactions which take place both in the batteries, mentioned above, and also in other liquids through which the current may be sent.

He must be able to measure the strength of an electric current, and he is strongly recommended to master thoroughly the law of Ohm, regarding the mutual relations of electromotive force, resistance, and strength of current.

He ought to be acquainted with the so-called polarisation of metallic plates between which a current passes through a liquid, and to show how this is avoided in Grove's battery.

He ought to be able to give a clear description of some one form of the electric telegraph.

He ought to be acquainted with the physiological effects, and with those of light and heat produced by the voltaic current; and to show the dependence of the heat on the strength of the current, and on the resistance which it encounters.

It would also be well to master as much of the phenomena of induced currents as would enable the candidate to explain the action of the galvanizing apparatus used by medical men.

NOTE.—The candidate will perceive that this list is long because the objects to which he is to devote his attention are separately specified. Definition is thus given to his studies and their precise scope marked out for him. He is recommended to repeat with his own hands, as far as it is in his power to do so, the experiments which he finds described in good handbooks of Natural Philosophy; this will give a certainty to his knowledge and an interest to his pursuits which mere reading can never confer. The first requisite demanded of him on his examination will be that, however small his knowledge, it shall be well digested and sound.

Text-Books:—Lardner's *Handbook of Natural Philosophy; Natural Philosophy*, by Dr. Golding Bird and Mr. Brooke.

### Subject X.—Inorganic Chemistry.

The general principles of chemical philosophy. Laws of combination. Volume weights. Combining weights. Atoms and molecules. Chemical symbols and their use in the explanation of chemical changes. Quantivalence.

The non-metallic elements:

*Hydrogen.* Water. Chemical composition and properties. Adaptation for domestic purposes. Hardness, permanent and temporary.

*Oxygen.* Combustion.

*Sulphur.* Sulphuretted hydrogen. Sulphurous acid, sulphuric acid, hyposulphurous acid, hyposulphuric acid. Manufacture of oil of vitriol. Bisulphide of carbon.

*Chlorine.* Hydrochloric acid. Hypochlorous acid. Bleaching agents and theory of bleaching. Chloric acid and perchloric acid. Chloride of nitrogen. Chlorides of carbon.

*Bromine.* Hydrobromic acid and bromic acid.

*Iodine.* Hydriodic acid. Iodic acid, periodic acid.

*Fluorine.* Hydrofluoric acid.

*Nitrogen.* Ammonia. The oxides of nitrogen.

*Phosphorus.* Phosphoretted hydrogen. Hypophosphorous acid, phosphorous acid. The several modifications of phosphoric acid: ordinary phosphoric, pyrophosphoric, and metaphosphoric acids. Theory of polybasic acids. Chlorides of phosphorus. Manufacture of matches.

*Carbon.* Marsh gas. Carbonic oxide. Carbonic acid. Olefiant gas. Manufacture of coal gas. Nature of flame.

*Silicium.* Silicietted hydrogen and silicic acid. Hydrofluosilicic acid.

*Boron* and boracic acid.

The metals: *Potassium.* Manufacture of nitre. Manufacture of gunpowder. Theory of the action of gunpowder. *Sodium.* Manufacture of soda.

*Barium. Strontium. Calcium.* Mortars.

Spectrum analysis; its principles and applications.

*Magnesium, Aluminium.* Manufacture of glass and porcelain.

*Manganese. Iron.* Composition and properties of cast iron, wrought iron, and steel.

*Cobalt. Nickel. Chromium. Zinc. Cadmium. Copper. Lead.* Manufacture of white lead.

*Bismuth. Mercury. Tin. Arsenic.* Course of analysis in cases of poisoning.

*Antimony. Silver. Gold,* and *platinum.* Principal compounds of the metals with the non-metallic elements.

Outline of qualitative analysis. Reactions of the principal mineral acids and bases. Course pursued in the application of these reactions to the analysis of a mixture of several acids and bases.

The following is the list of Apparatus and Re-agents with which Candidates make their analysis at the examination:—

#### Apparatus.

| | | |
|---|---|---|
| Test tubes and stand. | Iron spoon. | Platinum wire and foil. |
| Metal filter stand. | Tongs. | Funnels. |
| Wash bottle containing distilled water. | Pestle and mortar. | Cut filters. |
| Spirit lamp. | Porcelain dishes. | Sulphuretted hydrogen apparatus. |
| Black blowpipe. | Watch glasses. | Platinum crucible. |
| Charcoal for blowpipe experiments. | Porcelain crucible. | Herapath's blowpipe. |
| | Triangles. | Stirring rods. |
| | Test tube cleaner. | |

RE-AGENTS.

*In the liquid state.*

| | | |
|---|---|---|
| Sulphuric acid. | Ammonium, oxalate. | Acetic acid. |
| Hydrochloric acid. | Sodium, phosphate. | Hydrofluosilicic acid. |
| Nitric acid. | Barium, chloride. | Lead, acetate. |
| Hydrosulphuric acid. | Calcium, chloride. | Iron, sesquichloride. |
| Potassa. | Lime water. | Potassium, ferrocyanide. |
| Ammonia. | Calcium, sulphate. | Potassium, sulphocyanide. |
| Ammonium, chloride. | Potassium, sulphate. | Platinum, chloride. |
| Ammonium, sulphide. | Magnesium, sulphate. | Silver, nitrate. |
| Ammonium, carbonate. | Potassium, chromate. | |
| Ammonium, molybdate. | Oxalic acid. | |
| | Tartaric acid. | |

*In the solid state.*

| | | |
|---|---|---|
| Sodium, carbonate. | Borax. | Blue and red litmus paper. |
| Potassium, nitrate. | Lime. | |
| Potassium, cyanide. | Iron, sulphate. | |

**Subject XI.—Organic Chemistry.**

Definition of organic bodies. Their ultimate analysis. Calculation of an empirical formula. Methods of controlling an empirical formula. Determination of the molecular weights of organic acids and bases. Determination of the vapour-density of volatile bodies. Law of substitution. Synthesis of organic compounds.

The chemical history of the Cyanogen group. Cyanogen. Hydrocyanic acid. Cyanic acid and urea. Fulminates. Cyanuric acid. Sulphocyanic acid. Chlorides of cyanogen.

Amylaceous and saccharine substances. Fermentation. Alcohol, and its homologues. Ethers, simple and mixed. Oxidation of alcohol, Aldehyde and acetic acid, and their homologues. Chloride of acetyl. Anhydrides, simple and mixed. Compound ethers. Diatomic alcohols and their acids. Glycol and oxalic acid. Triatomic alcohols. Glycerine. Fatty and oily bodies.

Tartaric and citric acids. Tannic acid.

Aromatic bodies. Benzoic alcohol, aldehyde, and acid; their derivatives, their homologues. Salicylous and salicylic acid. Gallic and cinnamic acid. Hippuric acid.

Ammonia and its derivatives. Amides and amines: their classification. Examples of natural alkaloids.

Principal colouring matters. Indigo and its derivatives. Examples of products formed by destructive distillation. Colours derived from coal tar.

The chief constituents of the vegetable and animal organism, fibrin, albumen, casein, &c.

The chemical principles of agriculture.

The chemical principles of the process of nutrition and respiration in the animal organism.

Text-books. — Graham's *Elements of Chemistry*, Miller's *Elements of Chemistry*, Fownes' *Manual of Chemistry*, Bloxam's *Chemistry, Inorganic and Organic*, Galloway's *First and Second Steps in Chemistry*, Williamson's *Chemistry for Students*, Frankland's *Lecture Notes*, Roscoe's *Lessons in Elementary Chemistry*.

**Subject XII.—Geology.**

*General Principles.*

1. The division of rocks into three great classes, aqueous, igneous, and metamorphic.
2. The mode of formation of stratified rocks, such as ordinary marine strata of shales, sandstones, conglomerates and limestones

—delta formations—freshwater and terrestrial beds, and the signs by which you can distinguish these, such as the nature and mode of the occurrence of the genera of animals and plants that are found in them.

3. The theories of central heat, and of the consolidation of the earth from a state of igneous fusion.
4. The mode of occurrence of igneous rocks, intrusive bosses, lavas, volcanic ashes, and dykes.
5. Volcanoes and volcanic phenomena; the origin of volcanoes and the cause of eruptions.
6. Elevation and depression of land; the distribution and origin of mountain chains. Denudation of the earth's surface, origin of valleys, &c.
7. The ordinary mineral substances that enter into the composition of rocks, such as granites, diorites, basalts, &c. Gneissic rocks, sandstones, slates, shales, clays, &c. The origin of limestones. The origin of mineral veins or lodes.
8. Fossilization of organic bodies.
9. Table of geological formations, including those larger divisions absent in Britain.
10. Theory of metamorphism of rocks. Origin of cleavage.
11. Explanation of geological terms.
12. Definition of zoological terms used in geology, such as genus, species, bivalve and univalve shells, cephalopod, brachiopod, palæozoic, &c. &c.
13. The meaning of breaks in the succession of life (changes of genera and species) in the different formations.

*Stratified Formations, &c.*

1. Description of the Cambrian and Silurian strata, their physical characters, fossils, and any unconformities that exist in the British Silurian strata.
2. Description of the Old red sandstone and Devonian rocks, characters and fossils. Slate and slate quarries, building-stones, limestones, and marbles of these and the Silurian formations.
3. The Carboniferous limestone and Coal-measure series. Character, fossils, and mode of formation. Nature of the plants of the Coal-measure epoch. Their mode of growth. Origin of coal, its mode of occurrence, and how the vegetable matter became changed into coal. Mode of occurrence of the ironstone of the Coal-measures. Various kinds of coal, and the relation of anthracite coal to disturbance of strata. Limestone quarries, marbles, and building-stones. Clay pits and potteries of the Carboniferous strata. Fire clay. Alum shale, &c.
4. The Permian rocks. Their stratigraphical relations to the underlying strata, composition of rocks, fossils, and building-stones. Great break in the succession of life between the Palæozoic and Mesozoic or secondary strata.
5. The New red sandstone (or Trias), its subdivisions, fossils, building-stones, sand pits. Origin of rock salt and brine springs.
6. The Rhetic beds and Lias, their subdivisions, fossils, building-stones and hydraulic limestones, and clay pits.
7. Oolitic rocks. Subdivisions, leading marine and land fossils. Limestones, clay pits, coal, jet and other economic products.
8. The Purbeck and Wealden strata. Origin, subdivisions, chief fossils, building-stones, and marbles. Ironstones and limestones. Clays. Great break in the succession of marine fossils between the Oolitic and Cretaceous strata.
9. Cretaceous rocks. Subdivisions, lithological characters, fossils, building stones of Lower Greensand. Gault, its phosphatic nodules

and general uses. Upper greensand, chalk, &c. Building stones. Origin and uses of chalk-flints. Great break in the succession of marine fossils between cretaceous and eocene strata.

10. Eocene, or older Tertiary beds. Subdivisions, alternation of marine and freshwater beds, chief fossils, limestones and building stones, clays for bricks and potteries.
11. Miocene or middle tertiary strata, marine and freshwater, fossils, &c.
12. Crag. Its subdivisions, chief fossils. Origin of its phosphatic remains.
13. The glacial period, boulderclay, and evidence of old glaciers in Britain, &c. River gravels, &c. of post-tertiary age, and their contents.
14. Disturbance and denudation of strata in successive periods, &c.
15. Unconformities, faults, and fractures.
16. The causes of gaps in the succession of strata, or of breaks in the succession of life in time.
17. Water-bearing strata, and underground drainage. Artesian and other wells.
18. British rocks in which ores of metal are found, and the general mode of occurrence of these ores in beds of solid rock, in superficial detritus and in lodes.
19. The rules that ought to guide the miner in sinking for coal and other minerals, when the beds in which they lie are concealed by over-lying and unconformable strata.

Text-books.—Lyell's *Principles of Geology;* Lyell's *Elements of Geology;* Phillips' *Manual of Geology;* Jukes' *Manual of Geology;* Juke's *Geology for Schools;* Page's *Introductory Text-Book;* Page's *Advanced Text-Book;* Ramsay's *Physical Geology and Geography of Great Britain;* Woodward's *Recent and Fossil Genera of Shells.*

### Subject XIII.—Mineralogy.

A. Instruction in this subject should commence with a distinct understanding of the characters by which minerals, properly so called, are to be distinguished from other inorganic substances, and of the position of this science in relation to the collateral sciences of physics, chemistry, and geology.

B. Crystallography, as the essential means of appreciating the forms naturally assumed by almost all inorganic bodies, must commence with the needful geometrical definitions, proceed to the grouping of the various crystalline forms into systems, consider the laws by which the derivation of one form from another within the limits of the same system is determined, and explain the combination of various simple forms in the faces exhibited by compound crystals. It is also important to study the deviations from regularity which are commonly presented in nature, and the methods of measuring those elements which remain constant.

C. The various kinds of aggregation exhibited by crystalline substances are also to be considered, especially with reference to masses of the useful minerals, and of crystalline rocks.

D. Next in order will follow the other physical characters of minerals; 1st, in relation to their substance, as cleavage, fracture, hardness, and specific gravity: 2ndly, in relation to the effects of light, as transparency, refraction, lustre, and colour; 3rdly, as to their electric and magnetic properties.

E. The chemical characters of minerals, and the most convenient modes of testing them; 1st, by aid of the blowpipe; 2ndly, by the moist way.

F. Pseudomorphism, or the remarkable phenomena presented by minerals which have the composition of one mineral coupled with the form of another.

c. The physiography or systematic description of minerals. This last division should include all the more remarkable varieties as well as species, and should take especial note of the modes and places of occurrence, as well as of the association of particular groups of minerals in certain veins or formations.

As text-books may be recommended—

Professor Ansted's *Elementary Course of Mineralogy and Geology*. London. 1856.
Nicol's *Elements of Mineralogy*. Edinburgh, 1858.
Dana's *Manual of Mineralogy*, 1851.
Bristow's *Dictionary of Minerals*. Longman & Co. 1861.

For more advanced students—

Brooke and Miller's *Mineralogy*. London, Longman, 1852.
*On Crystallography*. Rev. W. Mitchell, in Orr's "*Circle of the Sciences.*" London, 1856.
Dana's *System of Mineralogy*. 4th edition. Putnam, 1854.
Naumann's *Mineralogie*. Leipzig. Williams and Norgate, London.
Breithaupt's *Paragenesis der Mineralien*. Freiberg, 1849.
Haidinger's *Handbuch der Mineralogie*. Vienna, 1845.

When it is intended to teach this subject with special reference to the practical working of minerals, the physiographical part will be occupied more particularly with certain of the useful species and their associated substances, and the following works may be consulted :—
W. J. Henwood *on the Metalliferous Deposits of Cornwall and Devon*, 1843.
Bischof, *Chemical and Physical Geology, translated by the Cavendish Society*. 1854.

### Subject XIV.—Animal Physiology.

Candidates must be prepared to answer questions upon the following points in Human Anatomy and Physiology :—

The plan of the human body and the arrangement of its parts.
The meaning of the terms organ and tissue.
The general structure and disposition of the principal organs and tissues.
The ultimate chemical composition of air, water, carbonic acid, urea; of protein, fat, starch, and sugar; of bone-earth and horn.
The meaning of the term function.
The general working of the body considered as an engine; its waste, and the mode in which that waste is made good.
The particular functions of the different organs.
The structure and working of the heart and blood vessels.
The nature of the lymphatics and lacteals.
The course of the circulation of the blood, and the evidence that it circulates.
The pulse and the sounds of the heart.
The regulation of the circulation by the nervous system.
The structure and properties of blood corpuscles.
The process of the coagulation of the blood.
The proximate chemical constituents of the blood, and the uses of that fluid.
The difference between arterial and venous blood. The way in which that difference is brought about. The working of the chest and lungs in respiration.
The difference in chemical composition between inspired and expired air. The daily loss of carbon and gain of oxygen. Stationary and tidal air.

The respiratory murmurs. The nature of asphyxia, and the necessity for fresh air.

The structure and uses of the kidneys. The daily loss of nitrogen in the shape of urea, of uric acid and of saline matters, by the kidneys.

The structure and uses of the skin.

The relations of the lungs, skin, and kidneys.

The structure and uses of the liver. The nature of the bile.

The development, distribution, and regulation of the heat of the body.

The composition of aliments: proteids, fats, amyloids, and minerals. Essential and accessory alimentary substances. Economy of a mixed diet.

The digestion and absorption of aliments.

Cilia and muscles; their structure and properties. The levers of the body. The structure of joints. Locomotion.

The structure and working of the larynx. Voice and speech.

The muscular sense. The organs of the higher senses, touch, taste, smell, hearing, and sight, and the manner in which they intermediate between the cause of the sensation and the expansion of the nerve. The adjustment of the eye to distances. The theory of the stereoscope.

Simple and compound sensations.

Auditory and ocular spectra. Auditory and optical delusions.

The general structure of the nervous system. The properties of nerves, and of the spinal cord, brain, and sympathethic. Vasomoter nerves.

Reflex actions, natural and acquired.

Text-books for Physiology.—Carpenter's *Animal Physiology*; Kirke's *Manual*; Huxley's *Lessons in Elementary Physiology*.

### Subject XV.—Zoology.

1. Candidates should have carefully mastered the definitions of the *sub-kingdoms*, *classes*, and *orders* of the Animal Kingdom. They should understand and be able to explain the meaning of the terms employed in such definitions; and they should be able to refer any specimens that may be placed before them to their proper *classes*.
2. Candidates should be prepared to give fair answers to questions relating to any or all of the following subjects, and they should be able to identify, refer to their proper orders, and if called upon to do so, describe, the objects enumerated in each section under the head of "types." In almost all cases these "types" are British animals.

   By the term Natural History, of such and such an object, is meant such an account of it as is to be found in any standard modern work on Zoology.

   i. The structure and mode of multiplication of infusorial animalcules and *Foraminifera*. The arguments which have been adduced for and against spontaneous generation. The luminosity of the sea, and the nature of the creatures which chiefly cause it. The natural history of the sponge of commerce. Types—*Spongia*, *Vorticella*.

   ii. The meaning of the terms, zoophyte, coral, coralline. Natural history of the red coral of commerce. Common coral and coral reefs. What such reefs are, where they are formed, and how they grow. Natural history of the common freshwater polype, or hydra, and of the "jelly fishes," or "medusæ" of the sea. Asexual multiplication as exhibited by these creatures. Types—*Hydra*, *Sertularia*, *Plumularia*, *Actinia*, *Corallium*, *Fungia*, *Oculina*.

iii. Starfishes, sea urchins, and *Holothuriæ*; their structure and habits, and the metamorphoses which they undergo. Natural and economical history of Trepang. Types—*Uraster, Echinus.*

iv. Natural history of the earthworm and the leech. Intestinal worms; their structure, propagation, and mode of entrance into animal bodies. Natural history of the *Rotifera*. Types—*Lumbricus, Hirudo, Distoma, Taenia, Ascaris.*

v. Natural history of Crustacea. The lobster and crayfish, as exemplifying zoological and teleological laws. The process of ecdysis. Parasitic, acorn shells, and fish lice, as cases of extreme metamorphosis. The water flea as exemplifying asexual multiplication. Types—*Cancer, Homarus, Astacus, Gammarus, Daphnia, Cyclops, Lepas, Balanus, Argulus.*

vi. Natural history of spiders, scorpions, and mites. The "lady insect," centipedes, and millipedes. Types—*Tegenaria, Scorpio, Scutigendra, Julus.*

vii. Insects; their mode of breathing as contrasted with that of spiders and crustaceans. The structure of their wings, and the mechanism of flight. The parts of the mouth and their modifications in beetles, bees, butterflies, bugs, and gnats. Structure of the eyes. Nature of stings, saws, and proboscises. Natural and economic history of the silkworm moth, of the silk moth, of the bee, of the cochineal insect. Natural history of plant lice, of bugs, flees, and lice. The house fly, blue fly, and gnats; wasps, humble bee, ichneumon flies, "black beetles," crickets, and locusts. The metamorphoses of insects. Types—*Melolontha, Blatta, Libellula, Phryganea, Culex, Aphis, Bombyx, Apis, Vespa, Musca.*

viii. The characteristic peculiarities of the nervous, circulatory, respiratory, and locomotive organs of mollusks in general. Organization of "sea mat" (*Flustra*). Acephalous and "lamp shells" (*Tunicata*). Natural histories of fresh-water and marine mussels. Nature of matter of pearl. Formation of pearls. Pearl fishery. Natural and economical history of the oyster. Organization of snails and slugs, periwinkles, limpets, whelks. Development of the young of the latter. Nidamental capsules. Cuttlefishes and squids. Paper nautilus. Pearly nautilus. The shipworm and *Pholas*. Mechanism by which mollusks bore. Types—*Pholas, Teredo, Teredinella, Unio, Mytilus, Ostrea, Pecten, Helix, Patella, Limacina, Buccinum, Conus, Sepia, Loligo, Argonauta, Nautilus.*

ix. Circulatory, respiratory, and reproductive organs of fishes. Their dentition. Natural and economical history of the lamprey, sprat, sardine, herring, pilchard, salmon, trout, eel, cod, haddock, sole, flounder, turbot, mackerel, tunny, sturgeon, skate, ray, dog fish, shark. Electrical fishes. Fishes which are capable of living in air. Pisciculture, or the artificial breeding of fishes. Types—*Amphioxus, Petromyzon, Squamipennes, Cyprinus, Perca, Acipenser, Lepidosteus, Raia, Squalus.*

x. Natural history of salamanders, newts, frogs and toads. Metamorphoses undergone by their young. Types—*Salamandra, Triton, Rana.*

xi. Circulatory and respiratory organs of reptiles as distinguished from those of fishes and amphibia. Natural history of snakes, lizards, crocodiles, turtles, and tortoises. Tortoise-shell. Moulting of the skin in reptiles. Types—*Coluber, Python, Anguis, Lacerta, Crocodilus, Testudo, Chelone.*

xii. Organs of locomotion, respiration, voice, circulation, and reproduction of birds. Structure and mode of growth of feathers,

Development of the fowl's egg. Artificial hatching. Migration, and instincts of birds. Natural history of domestic birds; of the ostrich, the apteryx, the penguin, and the dodo. Types—*Falco, Corvus, Columba, Picus, Phasianus, Ardea, Struthio, Anser.*

xiii. Organs of respiration, circulation, and reproduction of mammals. Production and nutrition of their young. Placental and implacental mammals. Nature of milk and of the lacteal glands. Peculiarities in the dentition of mammals. Natural and economic history of the domestic mammals; of the ivory and fur yielding mammals; of seals; of whales. The hybernation and migration of mammals. Characters of the orders of mammals. Types—*Cercopithecus, Vespertilio, Erinaceus, Lepus, Elephas, Sus, Cervus, Bos, Ovis, Felis, Phoca, Phocæna, Dasypus, Halmaturus, Ornithorhynchus.*

xiv. The distinctive peculiarities of man. The characters of the principal races of mankind, and their geographical distribution.

Text-books for Zoology.—Dallas's *Natural History of Animals* in Orr's *Circle of the Sciences;* Gosse's *Manual of Marine Zoology;* Professor Greene's *Manual of the Protozoa;* Rymer Jones's *Animal Kingdom.*

**Subject XVI.—Vegetable Physiology and Economic Botany.**

In this department the candidate will be expected to answer correctly questions on the following points:—

1. The properties of the principal elements entering into the composition of plants. Carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, chlorine, iodine, silicon, potassium, sodium, calcium, iron.
2. The composition and properties of the compounds forming the principal part of the structure of plants. Cellulose, starch, dextrine, sugar, fixed oil, gluten, albumen, caseine. The saline compounds forming the ashes of plants.
3. The composition and properties of peculiar vegetable products. Volatile oils. Acids. Colouring matters. Alkaloids. Neutral principles. Chlorophyll.
4. The origin and growth of the vegetable cell. The tissues of plants Cellular tissue. Intercellular organs. Epidermal tissue. Hairs Stomates. Vascular tissue. Woody tissue.
5. The structure and functions of the organs of plants. The root. Spongioles. Absorption and excretion. Nature of vegetable food. The stem. Structure of Exogenous, Endogenous, and Acrogenous stems. The leaf. The forms of leaves. Exhalation. Stipules and bracts. The flower. Calycine, Corollal, Staminal, and Carpellary leaves. Development and nature of pollen. Ovules or seed buds. Vegetable impregnation. Embryo. Seed. Fruits; their nature and forms. The nature of the reproductive organs in flowerless plants.
6. The composition and nature of vegetable substances used by man as food. Distinctions between heat-giving and flesh-forming foods. Structure and geographical distribution of plants yielding starch, sugar, oil, gluten, albumen, and legumin.
7. Properties of vegetable substances used in the arts and manufactures. Vegetable secretions used as dyes.—Indigo, madder, logwood, red sanders wood, quercitron, alkanet, arnotto, gall-nuts, myrobolans.
8. Materials used in the manufacture of textile fabrics.—Cotton, flax, hemp, coco-nut, jute, New Zealand flax.
9. Principal forms of timber trees, and their uses.—Oak, mahogany, teak, pine, &c.
10. Nature of tanning principles and plants yielding tannic acid.—Oak-bark, valonia, catechu, kino, divi-divi, betel-nut.

11. Gums, oils, and resins used in arts.—Gum arabic, benzoin, rosin, turpentine, camphor, essential oils, coco-nut oil, palm oil, other fixed oils, caoutchouc, gutta pertsha.
12. Substances obtained from the vegetable kingdom and used as medicines.—Opium, quinine, tobacco, jalap, scammony, gentian, aloes, rhubarb, senna, ipecacuanha, sarsaparilla, castor-oil, assafœtida, myrrh, nux vomica, hemlock.

Text-books for Vegetable Physiology and Economic Botany.—Henfrey's *Elementary Course of Botany;* Van Voorst. Carpenter's *Vegetable Physiology*, edited by Dr. Lankester; Bohn. Schleiden's *Principles of Scientific Botany;* Bohn. *A Manual of Structural Botany* by M. C. Cooke. Archer's *Popular Economic Botany;* Reeve and Co. Lindley's *Medical and Œconomical Botany;* Bradbury and Evans.

**Subject XVII.—Systematic Botany.**

In this department the candidate will be expected to demonstrate the structure of plants from living specimens.

1. The distinctions between the three great classes of plants, Dicotyledons, Monocotyledons, and Acotyledons. Also of the groups Gymnosperms, Rhizanths, Dictyogens, Acrogens, and Thallogens.
2. The characters of the following orders of British plants should be mastered, and the typical genera recognized, and their structure understood.
3. *Algæ.* The natural history and uses of sea-weeds. The microscopic structure of diatoms and desmids. Nature of the reproductive organs in this order. Types—*Navicula, Desmidium, Conferva, Fucus, Ceramium.*
4. *Lichens.* The natural history and uses of lichens. Structure of their reproductive organs. Types—*Graphis, Collema, Parmelia.*
5. *Fungi.* The natural history of mushrooms, puff-balls, moulds, blights, and toadstools. Their uses in nature. Types—*Agaricus, Bovista, Torula, Aspergillus, Morchella, Mucor.*
6. *Mosses.* The nature of their reproductive organs. Types—*Bryum, Sphagnum, Funaria.*
7. *Ferns.* Nature of their rhizomes. Herbaceous and tree ferns. History of Development, and nature of reproductive organs. Types—*Polypodium, Hymenophyllum, Osmunda.*
8. *Graminaceæ.* The history of grasses and their uses. Nature of the flower in this order. Useful plants of the order. Types—*Phleum, Hydrochloa, Panicum, Agrostis, Arundo, Spartina, Avena, Festuca, Hordeum, Triticum, Secale, Nardus, Anatherum.*
9. *Cyperaceæ.* Sedges. Types—*Carex, Scirpus.*
10. *Liliaceæ.* The lily tribe, its useful properties. Types—*Tulipa, Ornithogalum, Muscari.*
11. *Amaryllidaceæ.* The family of the narcissus, snow-drop, snow-flake. Types—*Narcissus, Galanthus.*
12. *Orchidaceæ.* The orchis family. Structure of reproductive organs. Types—*Orchis, Goodyera, Malaxis, Cypripedium.*
13. *Amentaceæ.* The family of the hazel, chestnut, oak, willow, birch, beech, poplar, and hornbeam. The uses of these plants as timber, &c. Types—*Quercus, Corylus, Fagus, Castanea, Betula, Myrica, Salix, Populus.*
14. *Urticaceæ.* The nettle and hop tribe. Its relations to *Moraceæ, Artocarpaceæ, Cannabinaceæ,* and *Ulmaceæ.* The nature of the stings of *Urtica*, and the bitter principle of the hop. Types—*Urtica, Parietaria, Humulus.*
15. *Euphorbiaceæ.* The spurge family. Foreign forms and their uses. *Croton, Cascarilla, Ricinus, Janipha.* Apetalous and Polypetalous forms. Types—*Euphorbia, Buxus.*

16. *Polygoneæ*. The buckwheat and rhubarb tribe. Types—*Polygonum, Rumex*.

17. *Primulaceæ*. The primrose family. Theory of the peculiar position of stamens. Types—*Primula, Lysimachia*.

18. *Labiatæ*. The dead nettle tribe. Peculiar properties of this order. Types—*Mentha, Salvia, Thymus, Nepeta, Lamium, Teucrium*.

19. *Scrophulariaceæ*. The scrophularia tribe. Nature of the poisonous properties of the order. Types—*Scrophularia, Digitalis, Verbascum, Veronica, Pedicularis, Melampyrum*.

20. *Boragineæ*. The borage tribe. Peculiarities of their epidermis. Useful species. Types—*Cynoglossum, Borago, Echium, Myosotis, Lithospermum*.

21. *Solaneæ*. The tribe of deadly nightshade, henbane, tobacco, and potato. Useful and poisonous species. Types—*Solanum, Atropa, Hyoscyamus, Datura*.

22. *Ericaceæ*. The heath tribe. Its distinction from *Epacridaceæ*. Types—*Erica, Arbutus, Vaccinium, Pyrola, Monotropa*.

23. *Compositæ*. The composite family. The number of species and geographical distribution. Structure of the sub-orders *Asteraceæ, Cichoraceæ*, and *Cynaraceæ*. Types—*Tussilago, Aster, Inula, Gnaphalium, Bellis, Artemisia, Achillea, Carlina, Carduus, Cichorium, Lactuca, Leontodon, Crepis*.

24. *Stellatæ*. The Stellate tribe. Its relation to *Cinchonaceæ* and *Caprifoliaceæ*. The properties and useful plants of Cinchonaceæ. Types—*Galium, Rubia*.

25. *Umbelliferæ*. Umbel bearing plants. Character of inflorescence and flowers. Nature of fruit. Structure of cremocarp. Properties of this order. Types—*Hydrocotyle, Sanicula, Eryngium, Apium, Sium, Bupleurum, Œnanthe, Crithmum, Angelica, Pastinaca, Daucus, Thaspium, Smyrnium, Conium, Coriandrum*.

26. *Cucurbitaceæ*. Melon, cucumber, and gourd family. Useful plants of this order. Type—*Bryonia*.

27. *Rosaceæ*. The rose, apple, cherry, and plum tribe. Forms of the fruit. The useful plants of this order. Types—*Prunus, Spiræa, Fragaria, Rubus, Geum, Rosa, Cratægus, Pyrus*.

28. *Leguminosæ*. The bean, pea, and clover family. Principal divisions of the family. Structure of the flowers and fruits. Useful plants of the order. Types—*Ulex, Trifolium, Vicia, Astragalus, Ornithopus*.

29. *Cruciferæ*. Cabbage, turnip, and mustard tribe. Structure of the flowers and fruits. Useful plants of the order. Properties. Types—*Nasturtium, Alliaria, Brassica, Sinapis, Armoracia, Iberis, Isatis, Cochlearia, Cakile*.

30. *Papaveraceæ*. The poppy tribe. Properties and mode of collecting opium. Nature of fruit. Types—*Papaver, Glaucium, Chelidonium*.

31. *Ranunculaceæ*. The crow-foot tribe. Structure of abnormal genera; *Aconitum, Aquilegia*, and *Delphinium*. Nature of poison in order. Types—*Ranunculus, Clematis, Helleborus, Pœonia, Anemone*.

Text-books for Systematic Botany.—Lindley's *Vegetable Kingdom*. For British Botany.—Bentham's *Handbook of the British Flora*, or Babington's *Manual of British Botany*.

## Subject XVIII.—Mining.

The Art of Mining embraces so wide a field of study that equal practical proficiency in its various branches is not to be expected; but those who wish to gain a general knowledge of it may be recommended to direct their attention to the subjoined heads, viz.:

I. Geology and Mineralogy, more particularly those portions of the sciences which bear on the following subjects,—the nature and position

in the earth's crust of the useful minerals, the classes of rock with which they are severally associated, the special character of heaves, throws, troubles, and all kinds of dislocation; the particular differences between beds and lodes, and their minerals, and the chief features of irregular repositories.

2. The methods of prospecting and searching at surface for ores and other minerals.

3. Breaking of ground; the various implements employed, their form, dimensions, and weight; boring for shots; the various modes of firing charges. Heavy charges, how calculated and fired; rules for ensuring safety.

4. Deep boring, under what circumstances applicable,—apparatus for; description of varieties in use; lining of bore-holes.

5. Management and supervision; payment of men employed at mines, at surface and underground, varying in principle with the different classes of operation; reasons for tut-work or piece-work, and tribute or bing-tale under different circumstances. Calculations for cost of driving, sinking, tramming, &c.

6. Physical principles of ventilation; practice of mines where simple natural ventilation is employed; ventilation of large areas and of deep or complicated workings by guiding the natural current; artificial means, and their details, for promoting ventilation. Precautions to be taken under specially dangerous conditions.

7. Illumination, of various kinds, their economy; safety lamps in all their best modifications; circumstances under which they should be employed; precautions in their use.

8. Mechanical division of the subject. Strength of materials used in mines; human and horse power, principles and construction of machines to which they are applied. Hydraulic machines: construction of the water-wheels, turbines, and pressure engines most suitable to the various operations of mining. Steam engines, for pumping and for winding; arrangement and construction of the varieties most in use. Form and dimensions of boilers. Pumps employed in mines, mode of placing them; construction of the lifts; materials and details of the rods, set-offs, counterbalances, cisterns, and catches. Circumstances under which dams are erected in shafts or levels; mode of building them.

Tubbing of water from shafts; conditions under which it may be done; details of the operation with various materials, wood, brick, stone, cast and wrought iron.

Rails, waggons, and tubs for underground conveyance; employment of horses and of fixed steam engines for this purpose.

Raising of the mineral through the shafts; various methods in use; chains, ropes (of hemp or wire), their weight, &c. Details of the best application of drums, cages, guides, keeps, and safety doors. Pulleys and shaft frames or poppet heads; protection against over-winding; safety clutches, &c. in case of breakage of rope.

9. Opening of ground; quarries and open work; driving of levels, various dimensions and directions according to circumstances; sinking of shafts, inclined or perpendicular; advantages of either kind under certain conditions; means of securing levels and shafts by timber or by walling; details of the various methods. Driving or sinking in heavy or running ground.

10. Working excavations; plan of laying them out, and means of security to be adopted whilst they are kept open. This will include the stoping of metalliferous veins, and the various modifications of post and stall, long-work, &c., which are applied to stratified deposits.

11. Travelling in shafts; prevention of accidents by proper fitting and diviidng; mode of placing ladders and sollars; lifting machine for men, construction and advantages of.

12. Dressing of minerals. Arrangement of dressing floors. Construction of crusher and stamps; washing of coal; jigging, concentration, and separation of metallic minerals.

The student may be advised among other sources of information to consult the following works:—

De la Beche's *Report on Cornwall and Devon.* Greenwell's *Treatise on Mine-Engineering.* Dunn on the *Winning and Working of Collieries.* Hedley on *Colliery Working and Ventilation.* Smyth's *Rudimentary Coal and Coal Mining.* Evidence before Committees of the Houses of Lords and Commons on *Accidents in Mines.* Reports of H.M. Inspectors of Coal Mines. Transactions of the Northern Institute of Mining Engineers.

## Subject XIX.—Metallurgy.

### I. Introduction.

On certain physical properties of metals. Action of heat, specific gravity, crystallization, fracture, malleability, ductility, tenacity, conductivity of heat and electricity, opacity, lustre, colour. General considerations on metallurgical processes. Modes of occurrence of metals in nature, ores, reduction, smelting, roasting, liquation, slags.

### II. Fuel.

General remarks, calorific power, calorific intensity, classification of fuels, wood, peat, lignite, coal, charcoal, coke, gaseous fuel and gas furnaces, charcoal burning, coke burning, typical varieties of coke ovens, comparison of fuels with respect to calorific power. This important branch of the subject is treated with much detail.

### III. Refractory materials employed in the construction of furnaces, crucibles, &c.

Fire-clays British and foreign, crucibles of various kinds, plumbago and its application to crucibles, manufacture of crucibles, fire-bricks, silica and its applications, Dinas fire-bricks, sand and sandstones.

### IV. Special Metallurgy.

*Copper.*—Compounds of special importance in the metallurgy of this metal fully described, such as the disulphide, oxides, &c., ores of copper, copper-smelting in reverberatory and blast furnaces, reactions occurring in the process, kernel-roasting, 'wet' methods, of extracting copper from its ores, assaying of copper ores by 'dry' and 'wet' methods, ship sheathing.

*Zinc.*—In describing the metallurgy of zinc and the following metals, the same plan will be followed as in describing the metallurgy of copper, that is to say, the compounds of special metallurgical importance will be first considered in detail, as well as the reactions upon which the various processes of smelting essentially depend, and the construction of the furnaces will be fully explained. Ores of zinc, English, Belgian, Silesian, and Carinthian methods of extraction, assaying of zinc ores brass, its history, properties and manufacture.

*Lead.*—Ores of lead, lead smelting in the 'ore-hearth,' low blast and reverberatory furnaces, lead-fume and various methods adopted for its condensation, assaying of lead ores.

*Silver.*—Ores of silver; smelting of silver ores with lead; cupellation; desilverization of lead by Pattinson's process, also by that of Parkes;

treatment of argentiferous copper by liquation; extraction of silver; amalgamation, the old Freiberg method and the Mexican; Ziervogel and Augustin's 'wet' methods; treatment of argentiferous copper-regulus; alloys of silver and copper; standard silver; assaying of silver ores and alloys.

*Gold.*—Modes of occurrence of gold in nature; extraction by amalgamation and by smelting with lead; chlorine-water as a solvent for the extraction of gold from certain ores; separation of gold from silver or parting by nitric and by sulphuric acids; alloys of gold with the preceding metals; standard alloys; assaying of auriferous ores and alloys.

*Mercury.*—Ores of mercury; extraction in the Almaden, Idrian, and Hähner furnaces; in retorts in admixture with reducing agents; assaying of the ores of mercury.

*Antimony.*—Ores of antimony; liquation of the native sulphide and its subsequent reduction by iron or other agents; alloys of antimony, type metal, &c.; assaying of the ores of antimony.

*Bismuth.*—Mode of occurrence in nature; its extraction from ores containing it by liquation; alloys of bismuth.

*Nickel.*—Ores of nickel; modes of extraction, generally by a combination of 'dry' and 'wet' processes; alloys of nickel, especially those known as German silver; assaying of nickeliferous ores and alloys.

*Cobalt.*—Ores of cobalt; smelting and preparation of zaffre and cobalt colours, smalts, &c.; separation of nickel; assaying of cobalt ores.

*Arsenic.*—Mode of occurrence in nature; arsenious acid or 'glass' of arsenic, generally obtained as a secondary product in the treatment of certain other ores, such as those of nickel, cobalt, &c.; modes of condensation of arsenical fumes; preparations of arsenical 'glass,'

*Tin.*—Ores of tin; smelting in reverberatory and blast furnaces; tin refining; varieties of tin in commerce; alloys of tin, with the preceding metals, bronze, gun-metal, bell-metal, &c.; assaying of tin-ores.

*Iron.*—Malleable iron; steel; pig-iron; ores of iron, direct extraction of iron in the malleable state from the ore; smelting of iron in the modern-blast furnace; construction of blast-furnaces and blowing machines; economic application of the waste gases; conversion of pig into bar iron in open hearths and in the reverberatory furnace; manufacture of steel by various methods. This department of the subject will be treated at considerable length.

*Various Metals.*—Platinum and its associated metals; cadmium; sodium; aluminium; tungsten; titanium; manganese.

### Subject XX.—Navigation.

1. *Elementary Principles.*—Problems relating to latitude, longitude; differences of latitude, and differences of longitude.

Relation between an arc of a parallel of latitude and an arc of the equator. Principles of plane sailing and middle latitude sailing. Principles of Mercator's sailing. Mercator's chart. Principles of great circle sailing. The compass and its corrections.

(1.) Variation. (2.) Deviation. (3.) Local attraction. (4.) General theory of deviation (Towson's Practical Information, first 50 articles). Correction of courses for variation, deviation, and leeway. The log. Correction of estimated distances run for errors in the log line and glass. Plane sailing. Traverse sailing. Middle latitude sailing. Mercator's sailing, with examples.

To find difference of longitude made on a traverse. Sea journal. A day's work. Practice of great circle sailing. Circular arc sailing. Tides. Winds. Cyclones. To find bearing of a circular storm; veering of wind; heaving to; and sailing from centre of gale. Construction of tables of meridional parts.

Description and use of sextant, with the theory, adjustments, and errors.

NOTE.—Candidates for certificates as teachers of Navigation will be required to possess a competent knowledge of the whole of the above syllabus, and to have obtained a certificate in elementary mathematics and passed in higher mathematics as far as spherical trigonometry inclusive.

For students.—To "pass," as far as principles of plane sailing. The compass and correction of courses.

For honourable mention.—As far as Mercator's sailing, with examples.

For third, second, and first class Queen's prizes, a proportionate knowledge of the remainder.

### Subject XXI.—Nautical Astronomy.

Definitions. Time, apparent, mean, sidereal, &c. Equation of time. To express interval of mean or sidereal time in parts of sidereal or mean time respectively. To convert arc into time, and conversely. To find Greenwich date. To take out right ascension of sun for a given mean Greenwich date.

Correction of altitudes. Dip. Parallax. Refraction. Augmentation of moon's semi-diameter. Reduction of altitude of a heavenly body observed at one place to what it would have been if observed at another. The chronometer and its use, error, and rate.

Latitude by meridian altitude of sun, and fixed star.

Latitude by meridian altitude of moon. To find Greenwich mean time of moon's meridian passage. To find semidiameter and horizontal parallax of moon for a given Greenwich date. To take out from Nautical Almanac moon's declination, &c.

To find local and Greenwich mean time of passage of a star over a given meridian on a given day. Latitude by altitude of sun, star, or moon *below* the pole and by pole star. Latitude by altitude of sun or other heavenly body *near* the meridian. Calculations of hour angles. Meridian distances. Right ascensions. Computations of time. Error and rate of chronometer. Computation of mean or apparent time at any place from observed altitude of a heavenly body. Longitude by chronometer. Error in hour angle from error in observed altitude. Variation of compass. Azimuth, altitudes, amplitudes, determination of true bearings. True azimuth from altitude of heavenly body and without observed altitude. True bearing of a point of land, &c., by observed angular distance from the sun. Variation of compass from observed amplitude of sun.

Deviation of compass, from Art. 50 to end of Towson's Practical Information. Sumner's method of finding longitude and latitude.

Method of double altitudes, Ivory's and direct. Error of chronometer by equal altitudes of sun and fixed star. To compute apparent altitude of a heavenly body when its true altitude is given.

Methods of clearing a lunar distance from the effects of parallax and refraction. To find Greenwich date corresponding to a given true lunar distance, &c. To find the altitudes when a lunar distance is taken from altitudes before and after taking the distance. To find the longitude by a lunar. Rate of chronometer by a lunar.

OBS.—In all the above problems the demonstration of the rules as well as *accurate* practical working is required.

NOTE.—Candidates for certificates as teachers will be required to possess a competent knowledge of all the above syllabus, and to have obtained a certificate in the elementary mathematics, and passed in higher mathematics as far as spherical trigonometry inclusive.

For students.—To "pass," a knowledge of the elementary principles, and finding latitude by meridian altitudes of a heavenly body.

For "honourable mention," the above, with variation of compass from altitudes and azimuths, and rate of chronometer, and longitude by chronometer, is required.

For third, second, and first class Queen's prizes, a more or less accurate knowledge of the remainder.

### Subject XXII.—Steam.

1. *General Properties of Steam.*—General effects of heat and cold, with practical applications of the principle. Law of expansion by heat not universal. Beneficial result of this anomaly. To ascertain the temperature of any substance. Pyrometer. Thermometer—Description—Graduation. Comparison of thermometers when differently graduated. Laws of cooling. Conduction. Conducting powers of bodies. Convection. Explanation of some natural phenomena by this law. Radiation. Radiating power of bodies. On what it depends. Land and sea breezes. Capacity for heat. Unit of caloric. Latent heat. Under what circumstances heat becomes latent. Heat sole agent in melting and vaporising bodies. Calorimeter. Sources of heat. Combustion. Temperature necessary for it. Boiling point. Temperature of elastic fluids. Vapour. Formation of dew. Distinction between vapour and steam. Boiling points of fresh and salt water. Distillation. High-pressure steam. Measure of steam by atmospheres. Steam when in contact and when not in contact with boiling water. Relation between pressure, density, and temperature of steam. Specific gravity of steam. Common, superheated and surcharged steam. Priming. Analysis of sea water.

2. *Steam Engine.*—General principles. Different kinds. Engines in use before Watt. Newcomen's engine. Its defects. Discoveries of Watt. Blowing through. Defects in atmospheric engines. Single acting and double acting engines. Expansion valve. Cornish—High-pressure or non-condensing engine. Marine steam engine. Different descriptions. Side-lever marine engine. Blow-valve. Stuffing boxes. Piston of steam cylinder. Working parts. Working of the slides, strap, gib, and cutter. Escape valve of cylinder. Parallel motion. Hall's condensers. Test cocks. Grease cocks. Grease cups of slides. Annular air-pump bucket. Annular delivery valve. Various kinds of slides. Cushioning. Lead. Lap, its effects. The eccentric. Throw and stops of ditto. To find the travel of the slide. Back-lash. Double eccentric. Throttle valve. Expansion valve and various kinds. Barometer or condenser gauge. Method of estimating pressure by it. Errors in this method, and correction of the same. Lubricators, &c. Number of engines in a steamer. Expansion cams and gear. Feed pumps. Bilge pumps. Modes of propulsion. Paddle wheels. Pitch, Reefing. Disconnexion and immersion of wheels. Brakes.—Modes of fitting. The screw propeller. Length, angle, pitch, slip, area of screw blade. Disconnecting and raising screw. Governors. Direct acting engines. Gorgon—Fairbairn's double cylinder, oscillating, trunk engines, &c. Engines for screw propellers. Direct acting, with and without multiplying gear. Oscillating horizontal and trunk engines. Double acting air-pump.

3. *Boilers.*—Description. Gear connected with them. Tubular boiler. Number of boilers. Steam chest. Safety valve. Waste. Steam funnel and drip pipe to steam gauge. Wash or dash plates. The funnel dampers. Reverse valve. Communication or stop valve. Blow-out cocks. Circulating pipes. Brine pumps. Brine valves. Refrigerators.

4. *Calculations.*—Methods of measuring efficiency of steam engines. Duty of an engine. Horse power. Mercantile or nominal horse power. Horse power from the evaporation in the boiler. De Pambour's theory. Velocity of maximum useful effect. To find evaporation of a condensing engine of given dimensions and horse power, the piston moving with a given velocity with and without expansion. To find the pressure in cylinder, knowing the effective evaporation. To find the diameter of a cylinder to work at a certain speed, knowing the evaporation. To find the evaporation in the boiler, knowing the diameter and velocity of piston and pressure of steam in the cylinder with and without expansion. Same for locomotive, Watt's engines, &c.

   The screw—to find its area. Angle of the helix or thread of the screw propeller—to find the pitch. The power exerted by a screw. How far slip depends on form and dimensions of the screw. Motion of paddle-wheels, &c. Consumption of fuel. Measure of locomotive performance of marine steam engines. To find the angle the crank has moved through when the piston is at a given distance from the top of the stroke. Amount of work developed by crank in a half-revolution—length of radius-bar in side lever engine. Work done in the up and down stroke of the air pump. The best temperature for the condenser of a steam engine. Qualities of fuel, &c.

5. *Practical working.*—Getting up steam. Mode of starting. Working engines at moorings. Priming—causes and remedies. Banking up and putting back fires, &c. Duties to machinery when under steam, boiler, fires, &c. Injection pipes. Kingston's valves. Leaks in engines. Bearings of engines. Expansive working. Management of fuel. Damages and repairs to boiler, &c., after accidents. Duties to engine, &c., on arriving in harbour.

6. *Indicator.*—The ends it fulfils. Description. Atmospheric line. Method of taking a diagram. The general configuration of diagram to be expected under various circumstances. The slide-diagram. Examination of Indicator-diagram when steam is throttled; when expansive gear alone used, and in other cases. To ascertain the horse-power of an engine by means of the indicator. To find quantity of water evaporated. Friction of steam engine without load. Diagram when there is no condensation. Diagram showing the relative motions of slide and piston at every point of the stroke.

Dynamometer. To find horse-power of engine by means of it.

The text books specially recommended are—*The Marine Steam Engine*, by Professor Main and Mr. Brown, R.N., Longmans and Co.; Main and Brown's *Indicator and Dynamometer*; De Pambour's *Theory of the Steam Engine.*

NOTE.—No certificate as a teacher of steam will be given unless the candidate has obtained a certificate in elementary mathematics and theoretical mechanics; and no first grade certificate, unless he has taken a certificate in higher mathematics.

### Subject XXIII.—Physical Geography.

The following very brief outline of the principal branches of this subject may be useful:—

*a.* So much elementary astronomy as relates to the position of the earth in the solar system, its magnitude and rotation, and the influence of the sun and moon on terrestrial phenomena.

*b.* So much of elementary physics and inorganic chemistry as includes the nature and mode of action of the physical forces and the composition of rocks.

*c.* So much of elementary geology and mineralogy as includes a knowledge of the nature of rocks, their superposition, succession, and disturbances.

*d.* So much of palæontology as includes a knowledge of the distribution of life in time.

I. The distribution of land. Form of land, continental and insular. Elevation of land. Mountains. Plateaux or table-lands. Low plains. Valleys. Deltas. Grouping of islands.

II. Phenomena of water. Oceans and inland seas. Composition and temperature of oceans. Movements of water. Tides and currents. Waves. Lakes. Rivers and river systems. Waterfalls. Circulation of water on the globe. Ice. Glaciers. Springs.

III. Phenomena of the atmosphere; its nature and composition. Effects of heat on air. Winds. Periodic winds. Storms of various kinds. Electric storms. Magnetic storms. Effects of moisture in the air. Dew. Clouds and rain. Estimate of rain-fall. Climate and weather.

IV. Volcanic and earthquake phenomena. Distribution of volcanoes. Volcanic groups. Nature of an eruption. Nature of earthquakes. Range of earthquakes. Statistics of earthquakes. Result of volcanic action and upheaval on the physical condition of the land.

V. Distribution of vegetation on the globe in space, horizontal and vertical. Influence of climate and soil on natural groups of plants. Representative forms of plants. Range of cultivated plants.

VI. Distribution of animals in space. Zones of height in the air and of depth in water. Corresponding forms of animal life in different zones or belts. Relation between parallels of latitude and zones of height or depth. Special distribution of certain classes and groups of animals.

VII. Distribution of plants and animals in time.

VIII. Ethnology. Families of the human race. Geographical limit of certain races. First introduction of the human family. Modification of the races of men. Influence of man on vegetation and on animals. Extinction of races by human influence. Influence of man on inorganic nature.

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